BHP Element

In preparation for future exploration missions to distant destinations (e.g., Moon, Near Earth Objects (NEO), and Mars), the NASA Human Research Program's (HRP) Behavioral Health and Performance Element (BHP) conducts and supports research to address four human health risks: *Risk of Behavioral Conditions; Risk of Psychiatric Conditions; Risk of Performance Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team; and Risk of Performance Errors due to Sleep Loss, Fatigue, Circadian Desynchronization, and Work Overload* (HRP Science Management Plan, 2008). BHP Research, in collaboration with internal and external research investigators, as well as subject matter experts within NASA operations including flight surgeons, astronauts, and mission planners and others within the Mission Operations Directorate (MOD), identifies knowledge and technology gaps within each Risk. BHP Research subsequently manages and conducts research tasks to address and close the gaps, either through risk assessment and quantification, or the development of countermeasures and monitoring technologies. The resulting deliverables, in many instances, also support current Medical Operations and/or Mission Operations for the International Space Station (ISS).

Risk to Mitigation Pathway

BHP Research utilizes a risk-to-mitigation strategy, which ensures that research will yield deliverables and products that are operationally relevant and acceptable (see Figure 1). Research begins by considering the deliverable in light of the known mission requirements. Working with operational experts, (e.g., flight surgeons, mission planners, astronauts), and intramural and extramural researchers, BHP Research assesses best practices that are currently implemented to determine if future work in a specific area is needed. In instances that prove future research is necessary, the BHP Research Element must then determine how to implement research that would enable the development of a deliverable that would adequately address the need within the context of the unique demands of exploration missions.

The BHP Risk to Mitigation strategy is based in part on the NASA Countermeasure Readiness Levels (CRL) and Technology Readiness Levels (TRL) (Mankins, 1995). The CRL/TRL levels provide a path for maturing countermeasures from concepts into operations. TRL levels are used by NASA as a systematic way to assess the maturity of a particular technology and provide a consistent comparison of maturity between different types of technologies (Mankins, 1995).

Analogs: A Critical Step in the BHP Pathway

Within this risk-to-mitigation strategy, BHP Research must identify optimal analogs for research studies that may be utilized to test or validate those needed products and/or deliverables. These studies may employ such platforms as the Shuttle, International Space Station and, in many cases, environments analogous to space flight such as the undersea facility NASA Extreme Environment Mission Operations (NEEMO) or the remote, isolated analog Haughton Mars (HMP). Analogs can be used to test feasibility, to validate the effectiveness of a countermeasure, and to establish or enhance acceptability, or face validity, of a product. The following discussion will integrate the use of analogs within the BHP pathway with NASA CRL and TRL levels discussed above to highlight the specific issues that need to be considered.

Analogs to Assess Feasibility

CRL step 5: Proof-of-concept testing and initial demonstration of feasibility and efficacy.

Establishing feasibility is a process for determining that it is possible to implement a protocol or countermeasure in the operational environment. For countermeasures or protocols that will eventually be evaluated during space flight, there are little if no precursor opportunities to test the product briefly in a microgravity environment to establish whether that specific protocol is feasible. Analog environments therefore permit investigators to ground test and determine feasibility for implementing a protocol, revealing gaps in a protocol that may need to be addressed before space flight implementation. This corresponds to a CRL step 5 that consists of *proof-of-concept testing and initial demonstration of feasibility and efficacy*.

Analog environments that provide the characteristics of space flight for feasibility testing include NEEMO, Antarctica, and Pisces. For example, studies evaluating the effects of autonomy have been conducted at the NEEMO analog. Kanas et al. (2010) utilized the NEEMO environment to characterize the effects of varying the degree of control over scheduling. Keeton et al. (2010) assessed changes in team interactions and team performance by varying both task criticality and novelty with specific tasks that were time lined during the mission. NEEMO offered not only a physical habitat similar to a space flight habitat, but also the mission tempo and mission objectives that accurately mimic space flight missions, as well as the opportunity and flexibility to tailor the NEEMO mission to the specific needs of each of these studies.

These analog studies allowed for the investigators to determine the feasibility of implementingan autonomy study, informing the development of a call for future research looking at autonomy in space flight.

Analogs to Further Countermeasure Development

CRL step 7: Evaluation with human subjects in controlled laboratory conditions simulating operational space flight environment.

From a behavioral perspective, simulating an operational space flight environment involves replicating the human experience of a mission in space as closely as possible. Preparing ways through which to predict, monitor, and mitigate deleterious health and performance outcomes for current space flight, an NEO mission and/or a Mars mission, requires a high-fidelity environment, mission scenario and sample population. Hence, countermeasures and technologies aimed at mitigating risk during such a mission require a validation study in an analog environment. This process corresponds to a CRL step 7, the evaluation with human subjects in controlled laboratory conditions simulating the operational space flight environment.

Currently, research is being conducted to assess light as a countermeasure for circadian entrainment, phase shifting, alertness, and performance. A study led by Brainard (2008) incorporates laboratory conditions that simulate an operational space flight environment. This space flight analog includes a mockup of the crew quarters on ISS, which incorporates the specific fabric and hence reflection specifications of the current space station.

Participants for these evaluations include those in the same age range as the astronauts, despite the fact that the laboratory has immediate access to university students. Since age is associated with circadian and sleep physiology, it is essential to mimic the astronaut population as accurately as possible along this parameter. This analog investigation therefore provides an opportunity to assess the countermeasure's effectiveness in a population and environment similar to space flight.

Analogs to Enhance Acceptability

In the behavioral realm, user acceptance or face validity of the countermeasure or technology is hugely important to integrating that deliverable into operations. While countermeasures transitioning to operations will be based on the best available scientific evidence, without user buy-in, these efforts risk having no impact in mitigating human health risks. Hence, analogs provide a useful platform for assessing user acceptance in the context of a 'space flight mission'.

An analogous environment, mission scenario, and population are key for establishing feasibility and user acceptance. The NEEMO analog provides a small team of astronauts in addition to individuals who work with the astronauts. Crew members evaluated the Psychomotor Vigilance Task at NEEMO, providing feedback to the study investigators regarding the tool's acceptability. Crew feedback was incorporated into the subsequent development of the tool, rendering it a more acceptable countermeasure for use on ISS, where it is currently being used to investigate the cognitive effects of fatigue during space flight.